

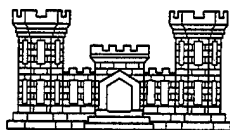
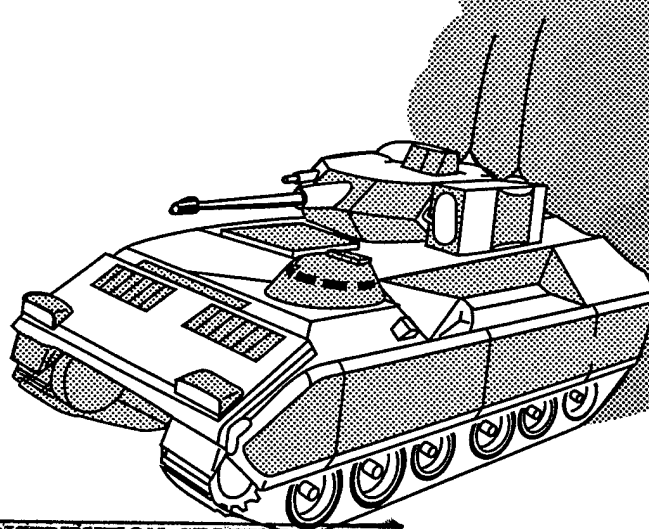


**U.S. Army
Environmental
Center**

USAEC AND USACERL TECHNICAL REPORT

DUST CONTROL MATERIAL PERFORMANCE ON UNSURFACED ROADWAYS AND TANK TRAILS

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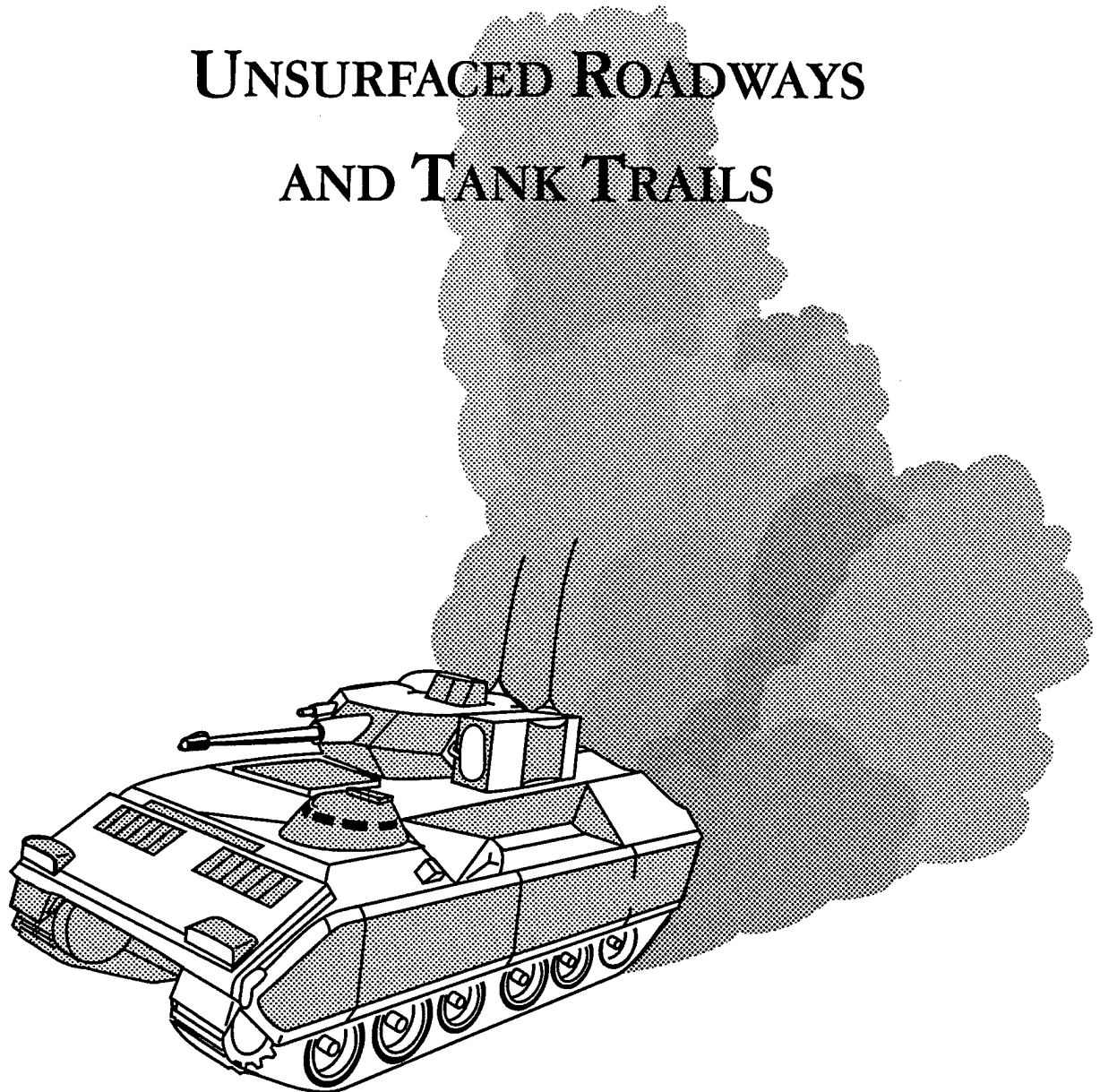
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REPORT DOCUMENTATION PAGE			Form Approved OMB No. 0704-0188	
<small>Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188), Washington, DC 20503.</small>				
1. AGENCY USE ONLY (Leave blank)		2. REPORT DATE September 1996	3. REPORT TYPE AND DATES COVERED Final; February 1996-September 1996	
4. TITLE AND SUBTITLE Dust Control Material Performance on Unsurfaced Roadways and Tank Trails			5. FUNDING NUMBERS	
6. AUTHOR(S) Dr. Dick L. Gebhart and Mr. Thomas A. Hale				
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) U.S. Army Construction Engineering Research Laboratories 2902 Newmark Drive Champaign, IL 61821-1076			8. PERFORMING ORGANIZATION REPORT NUMBER None	
9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES) U.S. Army Environmental Center (USAEC) Environmental Technology Division, Bldg E4430 Aberdeen Proving Ground, MD 21010-5401			10. SPONSORING / MONITORING AGENCY REPORT NUMBER SFIM-AEC-ET-CR-96196	
11. SUPPLEMENTARY NOTES USAEC Project Officer: Ms. Kim Michaels-Busch (410) 612-6845				
12a. DISTRIBUTION / AVAILABILITY STATEMENT Distribution Unlimited			12b. DISTRIBUTION CODE	
13. ABSTRACT (Maximum 200 words) Wheeled and tracked vehicle operation on dry, unsurfaced roadways creates tremendous amounts of dust as soil particles are dislodged and carried into the atmosphere through wind action. To assist installations public works, environmental, and natural resources managers in selecting durable and cost effective dust control products, a research/demonstration project on unsurfaced roadways at Ft. Hood and Ft. Sill was initiated during the spring of 1996. At Fts. Hood and Sill, each dust control product was applied to recently graded 500-yard segments of unsurfaced roadways according to manufacturers recommendations. This arrangement was repeated three times at each installation, allowing for statistical inferences to be drawn from the dust control data. Dust control data were collected at monthly intervals following product application. Levels of dust control associated with each product and the untreated control were evaluated using dust collection pans and photographic images captured immediately preceding and at five seconds after controlled vehicle traffic. Data were evaluated using analysis of variance and products ranked in order of effectiveness using mean separation procedures.				
14. SUBJECT TERMS Dust Control, Dust Control Agent, Helicopter Landing Pads, Tank Trails, Unsurfaced Roadways, Wheeled and Tracked Vehicles.			15. NUMBER OF PAGES 34	
			16. PRICE CODE	
17. SECURITY CLASSIFICATION OF REPORT Unclassified	18. SECURITY CLASSIFICATION OF THIS PAGE Unclassified	19. SECURITY CLASSIFICATION OF ABSTRACT Unclassified	20. LIMITATION OF ABSTRACT Unlimited	

DUST CONTROL MATERIAL PERFORMANCE ON UNSURFACED ROADWAYS AND TANK TRAILS



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Wheeled and tracked vehicle operation on dry, unsurfaced roadways creates tremendous amounts of dust as soil particles are dislodged and carried into the atmosphere through wind action. Numerous products have been developed for controlling dust on unsurfaced roadways, but very little data exist from replicated, large-scale field experiments designed to evaluate their effectiveness, durability over time, and cost. To assist installation public works, environmental, and natural resources managers in selecting durable and cost-effective dust-control products, a demonstration project on unsurfaced roadways at Fort Hood and Fort Sill began during spring 1996. Products evaluated included 38% calcium chloride, calcium lignosulfonate, proprietary polyvinyl acetate and acrylic emulsions, soybean processing by-products, and an untreated control. At Forts Hood and Sill, each dust control product was applied to recently graded 500-yard segments of unsurfaced roadways according to manufacturers' recommendations. This arrangement was repeated three times at each installation, allowing for statistical inferences to be drawn from the dust-control data. Dust-control data were collected monthly following product application. Levels of dust control associated with each product and the untreated control were evaluated using dust-collection pans and photographic images captured immediately preceding and at five seconds after controlled vehicle traffic. Data were evaluated by analyzing of variance and products ranked in order of effectiveness using mean separation procedures. Cost and performance data suggest that calcium chloride, calcium lignosulfonate, and soybean processing by-products provided good levels of dust control for periods exceeding 60 days. Levels of dust control for all products evaluated were better at Fort Sill than Fort Hood because of much lower tracked vehicle traffic volumes and coarser textured roadway surfaces. Deterioration of product performance over time was more rapid at Fort Hood because of very heavy tracked vehicle traffic and fine textured roadway surfaces.



This demonstration project was conducted for the U.S. Army Environmental Center under Reimbursable Order No. MIPR4196, "Tank Trail and Road Segment Dust Control." The technical monitor was Ms. Kim Michaels, U.S. Army Environmental Center, Aberdeen Proving Ground, MD 21010-5401.

The work was performed by the Resource Mitigation and Protection Division (LL-R) of the Land Management Laboratory (LL), U.S. Army Construction Engineering and Research Laboratories (USACERL). The USACERL principal investigator was Dr. Dick L. Gebhart, CECER-LL-R.

Special acknowledgment is due to Don Jones and Jerry Paruzinski, Fort Hood, and Terry Carroll and David Fritz, Fort Sill, for providing technical assistance and logistical support.

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Wheeled and tracked vehicle operation on dry, unsurfaced landscapes creates tremendous amounts of fugitive dust as soil particles are dislodged and carried into the atmosphere through wind action. During wet weather, these dislodged soil particles are subject to water erosion, which has the potential to carry them into surface waters and thereby reduce water quality and create sedimentation problems for area streams and wetlands (Cowherd et al. 1990). Fugitive dust generated from helicopter, wheeled, and tracked vehicle training exercises has the potential to create many different problems. Most notable of these are associated with safety, air quality, increased military vehicle maintenance requirements, and tactical considerations (Armstrong 1987). Dust clouds generated from helicopter landing pads and tank trails impair the visibility of military vehicle operators and increase the likelihood of accidents and injury. Excessive dust from tank trails acts as a respiratory irritant to military vehicle operators and is considered a safety and air quality hazard when it drifts into nearby housing and administrative areas or onto adjacent highways and streets. Excessive wear and tear on military vehicles and aircraft results from the intrusion of dust into engine and turbine compartments, air-filtering systems, and other sensitive mechanical and electrical components (Hass 1986). Finally, dust generated from helicopter and tank movement provides an unmistakable signature to enemy forces in a tactical scenario.

Although not directly related to mission and training problems mentioned above, dust also has adverse effects on vegetation near helicopter pads, roads, and trails. A covering of dust on leaf surfaces increases leaf temperatures (Eller 1977; Hirano, Kiyota, and Aiga 1995) and water loss (Ricks and Williams 1974; Fluckinger, Oertli, and Fluckinger 1979), while decreasing carbon dioxide uptake (Fluckinger, Oertli, and Fluckinger 1979; Thompson et al. 1984; Hirano et al. 1990; Hirano, Kiyota, and Aiga 1995). These physiological changes suggest that vegetation around helicopter pads, roads, and trails is susceptible to chronic decreases in photosynthesis and growth, which may eventually lead to accelerated erosion problems from lack of adequate roadside vegetative stabilization.

Since the 1940s, numerous products have been developed and used to control dust on unsurfaced landing zones, roads, and trails. Some products, such as used motor oils, industrial manufacturing wastes, and other petroleum based derivatives, have damaging environmental effects and their use is now prohibited. However, recent developments in dust-control technology have provided a number of environmentally safe materials similar in cost, efficacy, durability, and maintenance requirements, especially on unimproved roadways where somewhat rougher terrain may make traditional road maintenance more difficult and costly.

BACKGROUND

The relative merits of various agents for controlling dust on helicopter landing pads, tank trails, and unsurfaced roadways have long been the subject of heated debate. At one time or another, nearly every conceivable material has been sprayed onto unsurfaced roadways in an attempt to control dust, stabilize the road surface, and reduce vehicle maintenance costs (Kirchner 1988). Manufacturer's claims are abundant, yet Department of Army public works, safety, and environmental managers have very little actual data upon which to base product selection. An aggressive dust-control program requires a systematic evaluation of dust-control agents, application rates, and maintenance requirements to be labor and cost-effective. Therefore, large-scale, field-oriented, comparative product testing under carefully controlled and replicated experimental conditions is a necessary prerequisite for informed decision making.

OBJECTIVES

The primary objective of this report is to evaluate the effectiveness, cost, and maintenance requirements associated with several different dust-control agents when used on unsurfaced roadways and tank trails at Fort Hood, Texas, and Fort Sill, Oklahoma. This information will guide environmental and safety managers in developing an aggressive and cost-effective dust-control program. A secondary objective associated with this project is to develop a user-friendly, semi-quantitative method for evaluating the degree of dust control of the various dust-control agents using video imaging technology. Development of this technology has significant safety implications in that the level of dust obscuration (visibility) resulting from training exercises can be ascertained readily and corrective actions taken, if necessary. Development of this technology also may have the potential for further use in quantifying which combinations of dust-control agent application rates and soil types afford the greatest reductions in military vehicle signatures.

APPROACH

The first task in this research project was to divide tank trails selected for treatment into sections with similar soil types, surface characteristics, aspects, and slopes. Further discussion of this process is presented in Section 2.

Applying selected dust control agents to unsurfaced roadways and tank trails represented the next task. Details concerning the various dust control agents and application methods and rates are presented in Section 2.

Collecting, analyzing, and interpreting data obtained from video imagery and dust deposition pans represented the final task of this research project. Section 3 summarizes the results associated with each dust-control agent in terms of effectiveness, cost, and maintenance requirements.

The results of this project apply to most U.S. Army installations conducting wheeled and tracked vehicle training exercises.

SCOPE

The information in this report will provide guidance to Army public works, environmental, and safety managers in developing aggressive and cost-effective dust-control programs, based on large-scale field evaluations of promising materials.

**MODE OF TECHNOLOGY
TRANSFER**

U.S. standard units of measure are used in this report. Metric conversion factors are listed below.

**METRIC CONVERSION
FACTORS**

1 ft	=	0.304 m
1 acre	=	0.407 hectare
1 ton	=	907 kg
1 sq. yd.	=	0.836 m ²
1 cu. yd.	=	0.764 m ³
1 gal	=	3.78 l
1 lb	=	454 g

SELECTION AND CHARACTERISTICS OF DUST CONTROL AGENTS

Criteria against which to evaluate potential dust control agents include previous performance, applicability to a wide range of soil and climactic conditions, prewetting requirements, ease of application, soil surface penetrability, environmental friendliness, and curing time. Based on these criteria, 38% calcium chloride, calcium lignosulfonate, polyvinyl acrylic polymer emulsions, and soybean feedstock processing by-products were selected for use on tracked and wheeled vehicle roadways at Fort Hood and Fort Sill.

Contracts to supply and distribute 38% calcium chloride and one of the polyvinyl acrylic polymer emulsions, marketed under the trade names Dust-Fyghter and SoilSement, respectively, were awarded to Midwest Industrial Supply, Canton, Ohio. A contract to supply and distribute soybean feedstock processing by-products marketed under the trade name of SoyaSeal6, was awarded to Valley Products, Memphis, Tennessee. A contract to supply and distribute calcium lignosulfonate, marketed under the trade name of Lignin LS-50, was awarded to Prince Manufacturing, Quincy, Illinois. A contract to supply the second polyvinyl acrylic emulsion, marketed under the trade name of Top Seal, was awarded to Soils Control International, Killeen, Texas. The remainder of this report will refer to products by their trade names. This does not imply endorsement by the U.S. Army to the exclusion of other chemically similar materials marketed under different trade names. Appendix A provides a list of vendors capable of providing dust-control products and related services. This list is not all-inclusive but is considered representative, based on currently available information. It should be noted, however, that the performance of many of these vendors' products has not been established, and potential customers considering the use of products not specified in this report are encouraged to consult researchers at USACERL or U.S. Army Waterways Experiment Station for further information.

Dust-Fyghter, a 38% calcium chloride solution, is a hydroscopic surface penetrant that binds fine soil particles together by absorbing moisture from the air. Dust-Fyghter has been used effectively on gravel roads throughout the United States by state Departments of Transportation for dust control on unsurfaced roads. This extensive use indicates its ease of application and adaptability to a wide range of soil types and climactic conditions. Dust-Fyghter also offers good soil surface penetrability, especially if soils are somewhat damp from recent precipitation or application is preceded by prewetting. Curing times are relatively short (0 to 4 hours) depending on weather conditions. Dust-Fyghter can be applied with a water truck or asphalt distributor capable of metered application at rates generally between 0.45 and 0.55 gallons per square yard.

Calcium lignosulfonate (Lignin) has been used extensively by Departments of Transportation in the southwestern United States and the forestry industry in the western and southeastern United States for dust control on unsurfaced county and logging roads, respectively. The wide range of soil and climactic conditions encountered under these circumstances attests to Lignin's broad applicability. Lignin also offers good soil surface penetrability, especially if soils are somewhat damp from recent precipitation or application is preceded by prewetting. Dampened soils are not, however, a prerequisite for effective application. Curing time is minimal (0 to 4 hours) and road use can be resumed immediately following application. Lignin can be applied with a water truck or asphalt distributor capable of metered application at rates generally between 0.45 and 0.65 gallon per square yard.

SoilSement, a polyvinyl acrylic polymer emulsion, produces a soil surface binding film that retards dust formation. It has been used extensively throughout the United States by various mining industries for dust control on haul roads and stockpiles. The product is supplied in a concentrated form and must be diluted with water before application. Manufacturers' testing indicates that with slight variations in dilution (1:1 to 1:7 volume ratios of SoilSement to water) and application rates, SoilSement is suitable for use under all types of soil and climactic conditions. SoilSement provides good soil surface penetrability. Although penetrability is improved by prewetting soil surfaces, SoilSement does not require prewetting of road surfaces before application to be an effective dust control agent. Curing time is minimal (0 to 4 hours) and road use can be resumed immediately following application. SoilSement can be applied with a water truck or asphalt distributor capable of metered application at rates generally between 0.45 and 0.65 gallon per square yard.

SoyaSeal6, a soybean feedstock processing by-product, binds soil particles together and forms a solid, long-lasting, non-dusting surface. It is a relatively new proprietary soybean manufacturing by-product, and it has been used on a wide variety of soils with good results by the Iowa, Minnesota, and Kentucky Departments of Transportation for dust control on unsurfaced county roadways. SoyaSeal6 has somewhat limited soil surface penetrability (1 to 1.5 inches), offset by very good soil surface particle binding properties. Prewetting is not necessary for good performance. SoyaSeal6 is applied at rates between 0.4 and 0.5 gallon per square yard. For ease of application and best results, it must be applied at temperatures exceeding 135 degrees Fahrenheit with an asphalt-type distributor. Curing times following application are minimal (0 to 1 hour). One of the potential drawbacks to widespread use of this product is its limited geographic availability. SoyaSeal6 is manufactured in Tennessee, and a similar product is manufactured in Iowa. Costs for supplying and distributing these products on roadways is relatively reasonable (\$4,000-5,000 per mile) within a 100-mile radius of Memphis, Tenn. or Des Moines, Iowa. Beyond this distance, transportation costs

associated with heated distribution trailers become excessive and may limit wide geographic use (Table 5).

Another proprietary polyvinyl acrylic polymer emulsion, Top Seal, has been used successfully on road construction projects throughout the eastern and southeastern United States for dust control. The product is supplied in a concentrated form and must be diluted with water before application. Through variation in dilution (1:1 to 1:6 volume ratios of Top Seal to water) and application rates, it can be used on all types of soils under any climatic condition. Top Seal has excellent soil surface penetrability characteristics (2 to 3 inches) and does not require prewetting. For maximizing dust control, however, manufacturers' recommendations suggest an initial application followed by a second application approximately one hour later. Curing time following the second application is relatively short (1 to 3 hours). This product is one of the more expensive of all potential dust control agents. Costs range from \$5,000 to \$10,000 per mile, depending on number of applications, dilution rates, and road widths. Top Seal can be applied with a water truck or asphalt distributor capable of metered application at rates between 0.45 and 0.55 gallon per square yard.

SITE PREPARATION AND PROJECT DESIGN

With assistance from environmental personnel at Fort Hood, several tank trails were evaluated for treatment with dust-control agents based on similarities in soil types, slopes, and landscape positions. Based on these evaluations, two tank-trail segments of West Range Road and one tank-trail segment of Turkey Run Road were selected to receive dust control agent applications. The selected segments on West Range Road occur on the Speck-Tarrant-Purves soil association, have moderately shallow clayey/loamy surface textures underlaid by limestone (McCaleb 1985), and are level to slightly undulating with northeast-southwest directions of travel. The selected segment on Turkey Run Road occurs on the Denton-Purves soil association, has a clayey surface texture underlaid by limestone (McCaleb 1985), and is nearly level with an east-west direction of travel.

With assistance from natural resources personnel at Fort Sill, several unsurfaced roadways were evaluated for treatment with dust-control agents based on similarities in soil types, slopes, and landscape positions. Based on these evaluations, two roadway segments of South Boundary Road-Quanah Range and one segment of Tower Two Road were selected to receive dust-control agent applications. The selected segments on South Boundary Road-Quanah Range occur on the Foard soil series, have silty loam surface textures (Mobley and Brinlee 1967), and are nearly level with east-west directions of travel. The selected segment on Tower Two Road occurs on the Lawton soil series, has a loamy texture (Mobley and Brinlee 1967), and is nearly level with a north-south direction of travel.

Each of the three roadway and tank trail segments selected at Forts Hood and Sill were subsequently divided into six 0.3-mile-long sections in preparation for application of dust-control treatments. Prior to dust-control agent application, all roadway and tank trail segments at Forts Hood and Sill were graded to remove excess surface material, potholes, and washboarding. Magnetic traffic counters then were installed under roadway and tank trail segments to record traffic volume and relate it to dust-control agent effectiveness and durability. Following grading and traffic counter installation, each 0.3-mile-long roadway and tank trail section at Forts Hood and Sill received one of the following randomly assigned dust-control treatments: Dust-Fyghter, SoilSement, SoyaSeal6, Lignin, Top Seal, or no treatment at all. This arrangement resulted in a total of three 0.3-mile sections receiving each dust-control treatment at both Fort Hood and Fort Sill. For statistical analyses, this arrangement was classified as a randomized complete block experimental design with three replications.

In collaboration with Range Control, arrangements were made to apply dust-control materials at Fort Hood and Fort Sill during the week of 1 June 1996. Lignin and Dust-Fyghter were applied at a rate of 0.50 gallon/square yard using tanker trailers equipped with 12-foot spray bars. Top Seal and SoilSement were diluted with water (1:7 volume ratio of Top Seal or SoilSement to water) and applied at a rate of 1.0 gallon/square yard using water trucks equipped with 12-foot spray bars. SoyaSeal6 was applied at a rate of 0.4 gallon/square yard using heated (140 degrees Fahrenheit) tanker trailers equipped with 12-foot spray bars. All dust-control materials were applied to prevent surface puddling and provided for 6 inches of overlap between previously treated areas. Only half-widths of each road segment were treated at a time to allow for continued traffic and provide adequate curing times following chemical application. All roadway and tank trail segments received enough traffic that compaction using pneumatic rubber-tired or steel-wheeled rollers was not required.

Following application of dust-control agents to roadway and tank trail segments at Fort Hood and Fort Sill, normal traffic was allowed to resume and dust control/traffic test evaluations initiated. Dust control/traffic test evaluations of each treatment in each roadway and tank trail were conducted immediately following application and monthly for three months. Between each monthly traffic test, counters were used to estimate traffic volume, which was then related to product durability over time. Counter data were recorded monthly.

FIELD DEMONSTRATION

DUST CONTROL EVALUATION TECHNIQUES

During each traffic test, dust control was evaluated using two different techniques. On each side of treated roadways and tank trails, tared, oil-coated dust collection pans (Vallack and Chadwick 1992; Vallack 1995) were placed between 15 and 20 feet away from the center of the road or trail in positions that avoided possible contamination from adjacent treatments. After 24 to 72 hours, dust collection pans were retrieved, and reweighed, and the amount of collected dust determined. To supplement dust collection pan data, videographic images also were used during every traffic test to evaluate and quantify the degree of dust control afforded by the different agents. On respective sides of each treatment in each replicate, a video camera or white 1-square yard backdrops were set up opposite each other at a height of 3 feet to capture video images of the relative dust obscuration levels immediately preceding and at five seconds after controlled vehicle traffic traveling at 30 miles per hour. These images were digitized and analyzed for level of obscuration using computer image processing techniques to determine changes in the mean value level of images due to dust. For all video imaging analyses, the mean change ratio of the control treatments was standardized at a value of 100. For each treatment, mean change ratio indices below this standardized value indicated that levels of dust obscuration were less than those for the control treatment. Treatments having the lowest mean change ratio indices were the most effective at reducing levels of dust obscuration when compared to the control. Mean change ratio indices derived from video images captured during controlled traffic tests on roads and tank trails were used to provide semi-quantitative data concerning the relative effectiveness of each dust-control agent. Video image indices and dust collection pan data were analyzed using analysis of variance procedures and treatment means separated using Student-Newman-Keuls test (Steel and Torrie 1980).



FORT HOOD

Dust deposition pan data collected from Fort Hood on 2 July, 2 August, and 12 September 1996 are presented in Table 1 and represent averages from all treated trail sections. Dust-Fyghter provided the greatest levels of dust control for each evaluation date, followed by Lignin, SoyaSeal6, SoilSement, and Top Seal. When compared to the control, Dust-Fyghter, Lignin, SoyaSeal6, SoilSement, and Top Seal reduced dust levels by about 70%, 62%, 57%, 51%, and 27%, respectively, at the first evaluation. At the final evaluation on 12 September 1996, Dust-Fyghter, Lignin, SoyaSeal6, SoilSement, and Top Seal reduced dust levels by only about 25%, 7%, 4%, 12%, and 6%, respectively, when compared to the control. Product deterioration from the first to the last evaluation period was most pronounced for Top Seal, followed by SoyaSeal6, Lignin, and SoilSement. Conversely, Dust-Fyghter exhibited the lowest degree of product deterioration over time (Table 1). The combination of persistent drought conditions, no measurable precipitation during the evaluation period, and heavy tracked vehicle traffic volumes are probable reasons for the rapid deterioration in treatment effectiveness observed between 30 and 100 days.

Beginning about 15 to 30 days following product application, Top Seal treated tank trails started to develop noticeable potholing due to traffic-induced breakdown of the treated trail surfaces. Over time, this potholing became more pronounced as vehicle traffic shifted to and concentrated on stabilized sections of the tank trail surface, thereby resulting in further product breakdown and roadway destabilization. Similar trends also were observed for tank trail sections treated with SoilSement, SoyaSeal6, and Lignin about 60 days after product applications, but potholing and surface breakup were much less pronounced. Potholing and washboarding of road surfaces treated with Dust-Fyghter were minimal throughout the evaluation period.

During the 100-day evaluation period at Fort Hood, some differences noted between West Range and Turkey Run Roads have significant impacts on product performance. Foremost among these differences were traffic volumes. Traffic volumes on West Range Road for the periods 1 June to 2 July 1996, 3 July to 2 August 1996, and 3 August to 12 September 1996 were approximately 1,830, 1,680, and 2,610 vehicles, respectively. Traffic volumes on Turkey Run Road during these same time periods were about 8,160, 5,300, and 5,740, respectively. Please note, the magnetic traffic counters used in this evaluation were capable of monitoring traffic volumes in only one direction. Actual volumes probably could double if we assumed that traffic volumes are equal for both directions of travel. When compared to Turkey Run Road, lower traffic volumes on West Range Road resulted in increased durability and reduced potholing for SoilSement, SoyaSeal6, and Lignin. This is supported by dust deposition data from each treatment on Turkey Run and West Range Roads, presented in Appendix B.

A second factor that caused noticeable differences in product performance between West Range and Turkey Run Roads was vehicle speed. Subjective observations suggested that vehicle speed was much higher on Turkey Run Road compared to West Range Road. Increased vehicle speed on treated road surfaces results in increased rates of product deterioration (Armstrong 1987) and may account for differences observed between Turkey Run and West Range Roads.

Imaging analysis of video collected from controlled vehicle passes on each treated tank trail section also indicated that Dust-Fyghter provided the greatest level of dust control while Top Seal provided the lowest level of control (Table 2). Although imaging analysis data from Fort Hood do not directly support dust deposition pan data, they do indicate that video images can be used to objectively differentiate between best and worst treatments in terms of dust obscuration levels. There are several possible reasons why video images were not able to accurately rank treatments according to effectiveness. These include factors beyond the video operators' control, such as wind speed, wind direction, cloud cover, and sunlight intensity. Carefully accounting for these factors during video recording, with small refinements in video imaging techniques, should allow treatments to be ranked accurately using this technology. Although more expensive and less quantitative in nature than dust deposition pans for determining treatment effectiveness, video technology is much less time-consuming and could be substituted for dust deposition pans if only data concerning relative effectiveness are required.

FORT SILL

Dust deposition pan data collected from Fort Sill on 30 June, 29 July, and 10 September 1996 are presented in Table 3 and represent averages from all treated road sections. Dust-Fyghter provided the best dust control for each evaluation date, followed by Lignin, SoyaSeal6, SoilSement, and Top Seal. When compared to the untreated control, Dust-Fyghter, Lignin, SoyaSeal6, SoilSement, and Top Seal reduced dust levels by about 78%, 69%, 69%, 65%, and 49%, respectively, at the first evaluation. At the final evaluation on 10 September 1996, Dust-Fyghter, Lignin, SoyaSeal6, SoilSement, and Top Seal continued to reduce dust levels by about 65%, 45%, 43%, 25%, and 0%, respectively, compared to the control. Product deterioration from the first to the last evaluation period was most pronounced for Top Seal, followed by SoilSement, SoyaSeal6, and Lignin. Conversely, Dust-Fyghter exhibited the least product deterioration over time (Table 3). Under somewhat lighter tracked and wheeled vehicle traffic volumes when compared to Fort Hood, Dust-Fyghter, Lignin, and SoyaSeal6 continued to reduce dust levels effectively by at least 40% for periods exceeding 100 days.

Beginning about 60 days following product application, Top Seal treated roadways started to develop noticeable potholing and washboarding due to traffic-induced breakdown of the treated road surfaces. From 60 to 100 days

following product application, this potholing and washboarding became more pronounced as vehicle traffic shifted to and concentrated on stabilized sections of the tank trail surface, thereby resulting in further product breakdown and roadway destabilization. Similar trends also were observed for roadway sections treated with SoilSement between 60 and 100 days after product applications, but potholing and surface breakup were much less pronounced. Potholing and washboarding of road surfaces treated with Dust-Fyghter, Lignin, and SoyaSeal6 were minimal throughout the evaluation period.

During the 100-day evaluation period at Fort Sill, some differences noted between South Boundary-Quanah Range and Tower Two Roads have significant impacts on product performance. Foremost among these differences were traffic volumes. Traffic volumes on South Boundary-Quanah Range Road for the periods 3 June to 30 June 1996, 1 July to 29 July 1996, and 30 July to 10 September 1996 were approximately 530, 740, and 690 vehicles, respectively. Traffic volumes on Tower Two Road during these same time periods were about 3140, 6180, and 3600, respectively. Note again that the magnetic traffic counters used in this evaluation were capable of monitoring traffic volumes in only one direction of travel. Actual volumes probably could double if we assumed that traffic volumes are equal for both directions of travel. When compared to Tower Two Road, the lower traffic volumes on South Boundary-Quanah Range Road resulted in increased durability and reduced potholing for Top Seal and SoilSement. This conclusion is supported by dust deposition data from each treatment on Tower Two and South Boundary-Quanah Range Roads, presented in Appendix C.

A second factor that caused noticeable differences in product performance between South Boundary-Quanah Range and Tower Two Roads was the amount of aggregate material on road surfaces. Tower Two Road had substantially more surface aggregate material than South Boundary-Quanah Range Road, which reduced the effectiveness and durability of Top Seal and SoilSement. Top Seal and SoilSement are surface sealers/binders requiring relatively smooth, stable road surfaces to maximize performance. Vehicle movement across aggregate covered surfaces causes surface abrasion and shifting, which can quickly destroy the sealing/binding characteristics associated with Top Seal and SoilSement. Within 60 days following product applications, dust levels on Tower Two Road sections treated with Top Seal and SoilSement approached those of the untreated control section. Dust-Fyghter, however, is not a surface sealer/binder and performed well on both Tower Two and South Boundary-Quanah Range Roads. This result indicates that, unlike Top Seal and SoilSement, the performance of Dust-Fyghter is not affected by aggregate materials on road surfaces.

Imaging analysis of video collected from controlled vehicle passes on each treated roadway section also indicated that Dust-Fyghter, Lignin, and SoyaSeal6 provided the best levels of dust control, while SoilSement and Top Seal provided the worst levels of control (Table 4). Although imaging analysis data from Fort Sill do not directly support dust deposition pan data, they do indicate that video images can be used to objectively differentiate between best and worst treatments in terms of dust obscuration levels. Several possible reasons why video images were not able to accurately rank treatments according to effectiveness include factors beyond the video operators' control, such as wind speed, wind direction, cloud cover, and sunlight intensity. Carefully accounting for these factors during video recording, with small refinements in video imaging techniques, should allow treatments to be ranked accurately using this technology. Although more expensive and less quantitative in nature than dust deposition pans for determining treatment effectiveness, video technology is much less time-consuming and could be substituted for dust deposition pans if only data concerning relative effectiveness are required.

MATERIAL COSTS

Product costs per square yard for Fort Hood and Fort Sill are presented in Table 5. Lignin was the least expensive product, followed by Dust-Fyghter, SoilSement, Top Seal, and SoyaSeal6. Costs presented in Table 5 include labor, equipment, and all materials necessary for product application. Product costs can and will vary, however, due to transportation distances and product volumes required. For example, square-yard costs associated with a 10,000-square-yard job will be higher than those associated with 20,000 square yards. Table 5 illustrates product costs (SoilSement, SoyaSeal6, and Dust-Fyghter) on a similar project conducted at Fort Campbell, Kentucky. Product costs at Fort Campbell are based on treating 5.25 miles of road, whereas those for Fort Hood and Fort Sill are based on treating 0.3 mile of road. Some products, such as SoyaSeal6 and Lignin, are waste products from other industrial activities, and their cost and availability will fluctuate with the magnitude of these industrial activities.

All treatments except one of the polyvinyl acrylic emulsions (e.g., Top Seal) remained effective for 30 days following agent application at both Fort Hood and Fort Sill. At Fort Hood, heavy tracked vehicle traffic volumes combined with persistent drought conditions limited the efficacy of all treatments, especially between 30 and 100 days following treatment applications. Despite these conditions, calcium chloride and calcium lignosulfonate continued to reduce dust levels by at least half for periods of 60 days. Between 60 and 100 days, however, product effectiveness rapidly deteriorated, and dust levels for all treatments except calcium chloride approached those of untreated tank trail sections. At 100 days following application, even calcium chloride was reducing dust levels by only 25% when compared to untreated tank trail sections.

Under lighter tracked and wheeled vehicle traffic volumes encountered at Fort Sill, calcium chloride, calcium lignosulfonate, and soybean processing by-products continued to reduce dust levels effectively by at least 43% for periods exceeding 100 days. During the 100-day evaluation period, product deterioration was most pronounced for both polyvinyl acrylic and acetate emulsions. Conversely, soybean processing by-products, calcium lignosulfonate, and calcium chloride exhibited only modest deterioration in effectiveness during the 100 -day evaluation period.

Cost and performance data suggest that calcium chloride provides good dust control under a wide range of conditions for periods exceeding 90 days. Because of differences in traffic type and volume, soil types, and roadway/trail surface characteristics, product performance can and will vary. Where road surfaces have substantial aggregate covering, calcium chloride performs better than either polyvinyl acrylic and acetate emulsion. On roads with less surface aggregate covering, differences in performance between soybean processing by-products, polyvinyl acrylic and acetate emulsions, and calcium chloride are much less pronounced. However, based on data presented here, the performance and durability of calcium chloride are much better than those of both polyvinyl acrylic and acetate emulsions, soybean processing by-products, and calcium lignosulfonate across a wide range of traffic types, traffic volumes, and road surface characteristics. Thus it can be used successfully for dust control at Fort Hood and Fort Sill. Data indicate that polyvinyl acrylic and acetate emulsions probably should not be considered and that the high cost and limited geographic availability of soybean processing by-products also make them less desirable. Regardless of dust control product used, maintaining a given level of dust control on tank trails will require more frequent applications than on roadways supporting primarily wheeled vehicle traffic.

The use of video technology in this demonstration did indicate that video images can be used to differentiate objectively between best and worst treatments in terms of dust obscuration levels. Although more expensive and less quantitative in nature than dust deposition pans for determining treatment effectiveness, video technology is much less time-consuming and could be substituted for dust deposition pans if only data concerning relative product effectiveness are required.

Armstrong, Jeffery P., *Dustproofing Unsurfaced Areas: Facilities Technology Application Test (FTAT) Demonstration*, FY 86, Miscellaneous Paper GL-87-19/ADA185185 (U.S. Army Waterways Experiment Station [USAWES], August 1987).

Cowherd, C., P. Englehart, G.E. Muleski, J.S. Kinsey, and K.D. Rosbury, *Control of Fugitive and Hazardous Dusts* (Noyes Data Corporation, 1990).

Eller, B.M., *Road Dust Induced Increase of Leaf Temperature, Environmental Pollution*, No. 13 (1977), pp. 99-107.

Fluckinger, W., J.J. Oertli, and H. Fluckinger, *Relationship Between Stomatal Diffusive Resistance and Various Applied Particle Sizes on Leaf Surface*, *Z. Pflanzenphysiologie*, No. 91 (1979), pp. 173-175.

Hass, Robert A., *Dustproofing Unsurfaced Areas: Facilities Technology Application Test (FTAT) Demonstration*, FY 85, Technical Report GL-86-20/ADA176861 (U.S. Army Waterways Experiment Station [USAWES], December 1986).

Hirano, T., M. Kiyota, Y. Kitaya, and I. Aiga, *The Physical Effects of Dust on Photosynthetic Rate of Plant Leaves*, *Journal of Agricultural Meteorology*, No. 46 (1990), pp. 1-7.

Hirano, T., M. Kiyota, and I. Aiga, *Physical Effects of Dust on Leaf Physiology of Cucumber and Kidney Bean Plants*, *Environmental Pollution*, No. 3 (1995), pp. 255-261.

Kirchner, H.W., *Road Dust Suppressants Compared*, *Public Works*, Vol. 119, No. 13 (December 1988).

McCaleb, N.L., *Soil Survey of Coryell County, Texas*, United States Department of Agriculture, Natural Resources Conservation Service (May 1985).

Mobley, H.L., and R.C. Brinlee, *Soil Survey of Comanche County, Oklahoma*, United States Department of Agriculture, Natural Resources Conservation Service (August 1967).

Ricks, G.R., and R.J.H. Williams, *Effects of Atmospheric Pollution on Deciduous Woodland, II Effects of Particulate Matter Upon Diffusion Resistance in Leaves of Quercus Petraea*, *Environmental Pollution*, No. 6 (1974), pp. 87-109.

Steel, R.G.D., and J.H. Torrie, *Principles and Procedures of Statistics* (McGraw Hill, 1980).

Thompson, J.R., P.W. Mueller, W. Fluckinger, and A.J. Rutter, *The Effects of Dust on Photosynthesis and Its Significance for Roadside Plants*, Environmental Pollution Series A, No. 34, (1984), pp. 171-190.

Vallack, H.W., and M.J. Chadwick, *A Field Comparison of Dust Deposit Gauge Performance at Two Sites in Yorkshire, 1987-1989*, Atmospheric Environment, No. 26, (1992), pp. 1445-1451.

Vallack, H.W., *A Field Evaluation of Frisbee-Type Dust Deposit Gauges*, Atmospheric Environment, No. 29. (1995), pp. 1465-1469.

Vendors of Dust Control Products and Services

Actin

1102 E. Columbus Drive
East Chicago, IN 46312
(219) 397-5020

**CALCIUM CHLORIDE AND
RELATED PRODUCTS**

All Construction

4327 Franklin, Suite 103
Michigan City, IN 46360
(219) 874-9474

Ashland Chemical Company

P.O. Box 10298
Jackson, MS 39209

Dust Pro

725 S. 12th Place
Phoenix, AZ 85034
(602) 251-3659

Midwest Industrial Supply, Inc.

P.O. Box 8431
Canton, OH 44711
(708) 941-0205

Sicalco Ltd.

5240 W. 123rd Place
Alsip, IL 60658
(800) 942-4893

W&W Sales and Leasing Co.

P.O. Box 485
Edwardsville, IL 62025
(618) 656-5070

**SOILSEMENT AND
RELATED POLYVINYL
ACRYLIC AND ACETATE
EMULSIONS**

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60 Industrial Park Road
Plymouth, MA 02360

Benetech, Inc.
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Aurora, IL 60506

Dust Pro
725 S. 12th Place, AZ 85034
(602) 251-3659

Earth Systems International
28259 Dorothy Drive
Agoura Hills, CA 91301

Energy Systems Associates
P.O. Box 976
McLean, VA 22101

Executive Resource Associates
Suite 813, One Crystal Park
2011 Crystal Drive
Arlington, VA 22202

Midwest Industrial Supply, Inc.
P.O. Box 8431
Canton, OH 44711
(708) 941-0205

Soils Control International, Inc.
P.O. Box 1214
Killeen, TX 76540
(817) 526-5550

Soil Stabilization Products, Inc.
P.O. Box 2779
Merced, CA 95344

Feed Energy
3121 Dean Ave.
Des Moines, IA 50317
(515) 263-0408

**SOYBEAN PROCESSING
BY-PRODUCTS**

Prince Manufacturing Company
One Prince Plaza
P.O. Box 1009
Quincy, IL 62306
(217) 222-8854

Valley Products Company
384 E. Brooks Road
Memphis, TN 38109
(901) 396-9646

APPENDIX B

Mean dust deposition in dust collection pans expressed in pounds per acre of trail surface area per day (lb/ac/day) from treated tank trails at Fort Hood, Texas, on three dates about 30, 60, and 100 days following dust-control agent applications.

Date	Treatment Turkey	Tank Trail Name		
		West Range 1	West Range 2	Run
2 July 1996	Control	10.81	13.05	25.75
	Top Seal	5.12	7.26	23.94
	SoilSement	2.97	3.43	18.19
	SoyaSeal6	2.46	3.49	15.71
	Lignin	3.06	3.04	13.07
	Dust-Fyghter	2.33	2.55	10.28
2 August 1996	Control	17.01	23.05	47.03
	Top Seal	14.90	21.11	43.85
	SoilSement	13.31	13.20	35.62
	SoyaSeal6	12.45	14.27	31.03
	Lignin	11.26	13.29	25.67
	Dust-Fyghter	7.68	10.34	19.83
12 September 1996	Control	22.01	26.54	54.26
	Top Seal	20.94	24.99	50.37
	SoilSement	23.52	23.66	44.20
	SoyaSeal6	23.81	26.07	48.88
	Lignin	23.76	25.35	46.53
	Dust-Fyghter	17.29	21.71	37.23

Mean dust deposition in dust collection pans expressed in pounds per acre of road surface area per day (lb/ac/day) from treated roadways at Fort Sill, Oklahoma, on three dates about 30, 60, and 100 days following dust control agent applications.

Date	Treatment	Quanah 1	Road Name	
			Quanah 2	Tower Two
30 June 1996	Control	11.08	8.41	27.85
	Top Seal	6.80	7.06	10.56
	SoilSement	4.14	4.30	8.33
	SoyaSeal6	4.37	3.72	6.96
	Lignin	4.10	3.83	7.02
	Dust-Fyghter	2.93	2.98	4.83
29 July 1996	Control	9.13	9.83	20.52
	Top Seal	7.79	7.92	16.89
	SoilSement	7.16	4.65	18.40
	SoyaSeal6	4.56	3.92	7.83
	Lignin	4.32	3.85	8.48
	Dust-Fyghter	3.40	2.88	6.46
10 September 1996	Control	8.38	6.32	16.29
	Top Seal	8.85	5.96	18.01
	SoilSement	5.16	4.37	13.75
	SoyaSeal6	5.43	4.71	7.80
	Lignin	4.88	4.76	7.46
	Dust-Fyghter	3.04	2.81	5.22


TABLE 1

Mean dust deposition in dust collection pans expressed in pounds per acre of trail surface area per day (lb/ac/day) from treated tank trails at Fort Hood, Texas, on three dates about 30, 60, and 100 days following dust control agent applications.

Treatment	<i>Dates of Measurement</i>		
	02 July 1996	02 August 1996	12 September 1996
Control	16.54a*	29.03a	34.27a
Top Seal	12.11b	26.62a	32.10a
SoilSement	8.20bc	20.71b	30.46a
SoyaSeal6	7.22bc	19.25b	32.92a
Lignin	6.39bc	16.74b	31.88a
Dust-Fyghter	5.05c	12.63c	25.41b
* Treatment means within columns followed by the same letter are not significantly different at the 0.05 level of probability as determined by Student-Newman-Keuls test.			

TABLE 2

Differences in levels of dust obscuration (mean change ratio) from treated tank trails at Fort Hood, Texas, on three dates as determined by video image analysis.

Treatment	<i>Date of Video Imaging Measurements</i>		
	02 July 1996	02 August 1996	12 September 1996
Control	100.00*	100.00	100.00
Top Seal	154.26	84.66	283.13
SoilSement	50.40	82.33	164.70
SoyaSeal6	74.78	93.61	225.98
Lignin	-3.69	79.09	93.50
Dust-Fyghter	-32.77	69.18	57.11

* Mean change ratios below 100 indicate that levels of dust obscuration were less than those for the control treatment. The lowest mean change ratios are associated with the most effective treatments for reducing levels of dust obscuration.


TABLE 3

Mean dust deposition in dust collection pans expressed in pounds per acre of road surface area per day (lb/ac/day) from treated roadways at Fort Sill, Oklahoma, on three dates about 30, 60, and 100 days following dust control agent applications.

Treatment	<i>Dates of Measurement</i>		
	30 June 1996	29 July 1996	10 September 1996
Control	15.78a*	13.16a	10.33a
Top Seal	8.14b	10.87b	10.94a
SoilSement	5.59c	10.07b	7.76b
SoyaSeal6	5.02c	5.44c	5.98b
Lignin	4.98c	5.55c	5.70b
Dust-Fyghter	3.58d	4.24d	3.69c

❖ *Treatment means within columns followed by the same letter are not significantly different at the 0.05 level of probability as determined by Student-Newman-Keuls test.*

TABLE 4

Differences in levels of dust obscuration (mean change ratio) from treated roadways at Fort Sill, Oklahoma, on two dates as determined by video image analysis.

Treatment	<i>Date of Video Imaging Measurements</i>	
	30 June 1996	10 September 1996
Control	100.00*	100.00
Top Seal	121.18	120.43
SoilSement	111.14	99.65
SoyaSeal6	65.22	76.50
Lignin	81.81	26.27
Dust-Fyghter	61.03	-23.74

♣ *Mean change ratios below 100 indicate that levels of dust obscuration were less than those for the control treatment. The lowest mean change ratios are associated with the most effective treatments for reducing levels of dust obscuration.*

TABLE 5

Cost per square yard for dust control materials applied at Fort Hood, Texas, Fort Sill, Oklahoma, and Fort Campbell, Kentucky, in 1996.

Treatment	<i>Installations</i>		
	Fort Hood	Fort Sill	Fort Campbell
Control	\$0.00	\$0.00	\$0.00
Top Seal	\$0.56	\$0.66	Not available
SoilSement	\$0.40	\$0.47	\$0.33
SoyaSeal6	\$0.68	\$0.70	\$0.34
Lignin	\$0.28	\$0.30	Not available
Dust-Fyghter	\$0.33	\$0.40	\$0.28